BELLCOMM, INC.

SUBJECT: System Hold and Recycle Capability for the First Lunar Landing Mission - Part II. Case 310

DATE: February 27, 1967

FROM: R. L. Wagner

ABSTRACT

An intercenter task force has reviewed the "Lunar Mission Launch Flexibility." This memorandum records the second report of this group to the MSF Program Review on January 24, 1967.

Emphasis for the task force effort has been on the features of the lunar mission which are different from earth orbital missions and which therefore will be new to the Apollo organization. Among these features are the dynamic character of the mission trajectory depending on the day of launch and the inflexible nature of the launch opportunities. To accommodate the lunar mission situation, (1) training and other mission preparations are to be done using data for typical lunar missions, and (2) the system response time for targeting each new mission is receiving special attention. Two months has been established as the minimum interval from the time that the launch month and lunar landing site(s) are identified until the launch can occur.

The currently planned system capability appears consistent with the expected sequence of launch opportunities for the first lunar landing mission.

(NASA-CR-153757) SYSTEM HOLD AND RECYCLE CAPABILITY FOR THE FIRST LUNAR LANDING MISSION; PART II (Bellcomm, Inc.) 39 p

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SUBJECT: System Hold and Recycle Capability for the First Lunar Landing Mission - Part II. Case 310

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MEMORANDUM FOR FILE

I. INTRODUCTION

This memorandum is a record of the material presented at the MSF Review of January 24, 1967, under the title "Lunar Mission Launch Flexibility." The presentation represented the second report by an intercenter task force which was charged with reviewing the plans and capability of the Apollo system for conducting the first lunar landing mission. The task force review was particularly concerned with the sequence of mission opportunities and the total system capability for accommodating various kinds of launch delays.

The first task force report* was at the MSF Review of November 22, 1967. It outlined the expected sequence of mission opportunities, the mission preparations leading up to the first launch opportunity and the specific plans to cover slips in the launch from one opportunity to a following opportunity. The presentation recorded by this memorandum was concerned with answering a number of specific questions which remained at the end of the earlier presentation (on November 22, 1966).

II. CONCLUSIONS OF THE TASK FORCE REVIEW

The sequence of launch opportunities for the first lunar landing mission has been outlined based on the constraints for that mission. This sequence is described in terms of the length of the launch windows and intervals between launch opportunities, however, specific dates are not included. The sequence of launch opportunities is a resultant of the mission constraints and therefore not unique; however the effect of perturbing constraints has been investigated and no serious consequences areforeseen as a result of any anticipated changes in constraints.

The system capability, as presently known and planned, is compatible with the expected pattern of mission opportunities. Certain new capability is highlighted as required for the lunar missions and continued program attention should be given to the development of this capability.

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* System Hold and Recycle Capability for the First Lunar Landing Mission, Memorandum for File, R. L. Wagner, December 14, 1966.

[redacted]

III. PRESENTATION MATERIAL

The presentation outline is shown on Viewgraph 7. The four sections are described below and the viewgraphs associated with each section are identified:

1. Introduction (to the January 24 presentation)

The introduction contained a short review of the presentation of November 22, including the outline (Viewgraph 1) and selected highlights (Viewgraph 2 - 6). Viewgraph 2 shows the principal constraints which determine the launch opportunities. An important consideration is that the mission planning impact is nearly the same, whether the launch date alone is changed or the lunar landing site is changed as well. Preparing for a number of landing sites has a "one time" cost in lunar surface data analysis and map making, however, a change in launch date will upset all of the computer constants which are mission dependent and no two launch dates are served by the same set of constants.

Another important point with respect to Viewgraph 2 is the indication of "preferences" which are desirable but not mandatory. To a large degree these preferences can be favored by the distribution of the lunar landing sites and studies have been done to determine the relationships between lunar landing site position and mission characteristics. It appears that the lunar surface is considerably poorer in some of the desirable locations than in others and, therefore, is likely to seriously influence the final distribution of sites, i.e., mission preferences may be allowed to influence site selection but not completely control it.

Viewgraph 3 shows a sketch of the pattern of launch windows/launch opportunities with time intervals indicated. This pattern is not uniquely defined by physical constraints, but represents a focus which seems reasonable in view of all considerations. The defining of the series of launch opportunities is vital to a detailed review of system capability, and also to the specific planning for the first lunar landing mission.

System capability was evaluated using the system block diagram of Viewgraph 4 and the findings as of November 22 are shown on Viewgraph 5. With respect to the need for mission dependent data, strong emphasis was put on preparing the system using "typical" mission data which is representative of the family of lunar landing missions. The "actual" mission data is for the specific launch day and associated lunar landing site. All constraints and important vehicle parameters are the same for both sets of data. The purpose of using typical data is primarily that the commitment to a specific landing site and launch date cannot be done with confidence at the time that the mission data are first required.

Viewgraph 6 contains program requirements which appeared advisable as of November 22. The third one (Pacific Ocean injection) was removed from the list as of January 24, because lunar surface data obtained from Orbiter photographs indicated that there were no acceptable sites in certain regions where sites were desired. The inclination to favor Pacific Ocean injections is based on the high incidence of daylight launches; the capability to do it depends on finding landing sites in essentially two parallel strings, one north of the equator and one south. Based on the data from Orbiters I and II, it appears that landing sites may not be found sufficiently far north in the western half of the Apollo zone.

2. Mission Definition and Preparation

The five items covered in this section are listed on Viewgraph 8 and briefly discussed below:

Lighting Constraints at LM Landing

The lighting constraint at LM landing is one of the more influential constraints in determining the pattern of mission opportunities. The lighting pattern repeats every 29.5 days for a given landing site and this is the cadence of any pattern of launch opportunities set by lighting considerations. Since the sequence of launch opportunities is so directly affected, the validity of the current constraint (that the sun be between 7° and 20° above the eastern horizon) is rather continuously under review.

Viewgraph 9 points out that the 7° to 20° range is that span of sun angles for which shadowing is expected in the craters, but neither too little nor too much. These limits are thirteen degrees apart which is just adequate to assure that each landing site will be available at least once each month.* Another factor is the elevation angle of the astronauts line-of-site to the landing point, which

* Since the times of launch from earth and arrival at the moon are set by earth-moon geometry, the time of landing can only be controlled to within about 24 hours which is nearly equivalent to a 13° change in sun elevation angle referenced to the moon.

should be greater than the sun elevation angle. The line-of-site angle increases monotanically (slowly at first) as the LM descends and exceeds 20° for ranges to the landing point of about 5000 feet or less (see Viewgraph 9).

Viewgraph 10 illustrates how crater detection range varies with sun elevation angle for two viewing angles (14° and 38°) and also how visibility improves for viewing scenes to the side rather than directly ahead (in the vertical plane containing the sun and the viewer). When combined with the viewing angles expected during descent, this figure suggests that sun elevation angles between 7° and 20° could give reasonably good viewing conditions.

Viewgraph 11 shows the geometry for two simulations of the astronauts viewing conditions prepared in the form of a moving picture film. These simulations included the LM descent from high gate to a point about 40 feet above a simulated lunar surface and showed the astronauts' view for sun elevation angles of 10° and 60°. The film indicated a dramatic difference in viewing conditions with the ability to see craters very much impaired at the 60° sun angle.

It seems clear that the preferred lighting for LM landing is a narrow sector of sun elevation angles near the morning terminator. The lighting outside of this sector is considerably poorer and its adequacy is questionable. The 7° to 20° band of sun elevation angles is therefore a conservative lighting constraint, and having prepared for it, relaxing the limits would be relatively non-disruptive.

Duration of the Earth Launch Window

Launch operations interests are currently encouraging the longest possible earth launch window. The Apollo system has been designed with the capability of about four hours of launch window, however, the limits can be changed somewhat by trading off various factors.

The duration of the earth launch window is a function of the launch azimuth limits, as well as the declination of the moon. The azimuth limits in turn are a function of range safety, insertion tracking requirements and payload (Viewgraph 12). Earth orbital tracking, ARIA coverage and post injection coverage are also affected, but are not considered constraining for small changes in azimuth limits.

Insertion tracking (Viewgraph 13 and 14) requirements are set at three minutes minimum which translates into a launch azimuth spread of about 26°. The nominal 72° to

108° azimuth sector has historically been assumed as the bounds of the Apollo "sector of interest" and for this entire region one tracking ship could provide about two minutes of tracking data.

The launch window duration may be described in terms of probabilities assuming any day of launch is as likely as another. Viewgraph 15 shows curves for three conditions using data for Pacific injections between February and August 1968. Curve number 3 is peripheral in that the probability of a daylight launch is included. This curve would change drastically for Atlantic windows and is also a strong function of the lunar landing site location as well as the portion of the year which is included in the data. Curves 1 and 2 are much less sensitive to the factors affecting 3 and the theoretical probability distribution curves are very much like the ones shown on Viewgraph 15 for sampled data (Pacific injections, February through August, 1968).

The payload vs. launch window tradeoff is shown by Viewgraph 16 and 17. Translunar payload decreases parabolically as the launch azimuth deviates from due east (90° azimuth). At 72° or 108°, it is changing at a rate of about 100 lbs per degree and of course the rate increases linearly with azimuth deviation (the rate is linear with azimuth because the payload varies parabolically). Viewgraph 17 shows this payload rate combined with data on the time rate of change of launch window (which is a function of lunar declination). The curve shown is for 72° and Pacific windows, since it was judged that range safety considerations would more firmly limit the 108° edge of the launch sector. As a matter of record the same curve applies for the combination of 108° azimuth and Atlantic windows. For Pacific windows and 108° launch azimuth or Atlantic windows and 72° launch azimuth, the scale on the abscissa should be reversed.

It was concluded that nothing should be done to the system hardware or software and that there are operational tradeoffs which could make available the entire 4.5-hour launch window, if our AS-501 experience were good and it then seemed proper to do so.

Selection of Earth Orbit for Translunar Injection

The Apollo hardware has been built with the general capability for injecting on any of the first three earth parking orbits following earth orbit insertion. The planning has, for a long time, included a real time alternate involving translunar injection on the orbit following the nominal selection. Thus, as indicated on Viewgraph 18, either the first or second orbit could be the one selected as the nominal while retaining the real time alternate. Based on the advantages indicated on the viewgraph, the second orbit has been selected as prime for future planning.

Translunar injection on the first orbit provides very little time for earth orbital operations in some cases of interest. Viewgraph 19 supports the point that the translunar injection may occur less than one half orbit after earth orbit insertion, and therefore, the tracking may be limited to that which is provided by the insertion tracking ship.

Status of the Typical Mission Data Package

One of the outputs of the task force activities at the November 22 review was emphasis of the point that typical mission data were needed for exercising all aspects of the Apollo system, including those activities normally referred to as training. There are two basic reasons for this situation:

a) the training must be done for a family of missions rather than a single specific mission.

b) the data for the specific mission to be flown will not be available until a very short time before launch.

Viewgraph 20 outlines the status of the typical mission data package. Not indicated is the fact that the package includes several missions spanning a three-month period.

3. Hardware Recycle and Reschedule (Viewgraph 21)

The items included in this section are concerned with hardware and its capability to accommodate various delays. Viewgraph 5 indicates that there are no identified problems in holding for the duration of the launch window.

Minimum Recycle Plan in Event of a Scrub

Viewgraph 22 indicates a recycle plan requiring about 42 hours without any allowance for series repair. This contrasts with the 53-hour estimate which was current at the November 22 meeting. The reduction in time has been achieved primarily in the launch vehicle area. Batteries have recently had their lifetime extended from 72 to 120 hours because of an environment which is more favorable than was previously anticipated. Battery changes are therefore not required, at least for an initial recycle. Also there have been savings in the time required to do leak checks and calibration of the propellant utilization systems.

Reschedule Plan

There are two areas of concern at the time of the November 22 meeting. One was the ability to retest during the approximately 20 days available following a reschedule so as to achieve sufficient confidence in the launch readiness of the space vehicle. The other was the qualification of certain components (which were exposed to hypergolics) for a lifetime which would permit launching on the third month after failing to do so on the first and second months. Viewgraph 23 shows a reschedule plan which is believed to be practical and which should enable a launch decision for the month following a scrub. The capability of the hypergolic systems to meet the third month launch opportunity was given a better chance than in November. There are qualification programs planned to determine if the spacecraft systems have the required lifetime.

The need was established for center recommendations on how to best handle hypergolic systems for standby operation and also for a review of consistency in the procedures for the different subsystems.

Extended Hold Capability

A comment made at the November review stimulated a quick look at the capability of the space vehicle to hold through the twenty-four-hour period which would be necessary to span two successive launch windows. It appeared that there were no obvious problems in either the launch vehicle, or the spacecraft which clearly precluded this, however, the ground systems lack sufficient storage facilities for cryogenics and in particular liquid nitrogen.

In considering the desire to establish an extended hold capability the potential benefits should be considered. Holding is an alternative to recycling and the impact on overall mission strategy is to provide additional options in launch sequences. An extended hold could provide at least one pair of launch windows twenty-four hours apart in the monthly launch window sequence, however, the advantages* of this are conjectural at this point. If the work load associated with mission preparation is the limit on the number of launch windows, then the extended hold provides a variation of, but not an addition to the launch window sequence.

4. Summary (of the January 24 Presentation)

The summary covered two levels of information. The first was a brief review of the way in which LM lighting, earth-moon geometry and lunar landing site location(s) combine to determine the pattern of launch opportunities. The second was an overall review of the task force effort.

The major cycle in the pattern of launch opportunities follows the synodic month. As shown on Viewgraph 24, there are alternating periods during which lunar landings could and could not occur depending on the longitudinal spread of landing sites and the width of the elevation sector which the sun may be within. Increasing the range (sector) of acceptable sun elevation angles increases the duration of the period when landings could occur, while decreasing the duration of the period when landings could not occur. Eventually the period of no landings would become too short to support the retest and other activities necessary to reschedule a launch from one month to the following month.

Within the window set by lunar landing constraints, there are discrete launch opportunities which are determined by earth-moon geometry and efficient trajectory design. These launch opportunities are available only in a theoretical sense until specific mission planning is done to prepare for them. The amount of work which is involved in this preplanning is expected to be a major factor in determining how many launch windows we can "affort." The windows which might in a typical case have been selected for mission planning are indicated on Viewgraph 25. This selection is not arbitrary; it is expected that it will be based on available combinations of lunar landing site locations and LM lighting constraints. As indicated on Viewgraph 3, there are limits and/or ranges established for the length and spacing of the launch windows.

* So as to make it.

The data provided by Lunar Orbiter already suggest certain areas of the moon as being more probable landing sites. On Viewgraph 26 the dots indicate promising areas for which some orbiter data exist. The arrows indicate a subset of the Orbiter mission which is well distributed and for which there is good high resolution photography. Thus, there exists information from which a decision can eventually be made to land or not to land, i.e., no further Orbiter missions are required to support decisions on these sites. It can be seen that there are more possible site selection options which would support a 44-hour recycle than would support a 68-hour (3 day) recycle. In fact only a very restricted set of sites could support three launches per month with minimum spacing of 68 hours.

In perspective then, the planned sequence of launch opportunities has evolved consistent with the mission and hardware constraints. Because constraints and mission strategies can be convolved in several ways, there is more than one possible launch sequence, however, it is believed that the one being planned has good basic characteritics.

The summary of all of the task force findings contains two parts. The gross restrictions on the mission definition for the first lunar landing are shown on Viewgraph 27. The first lunar mission, by reason of these major restrictions and other minor ones, is a subset of all possible missions that the Apollo system is capable of performing. Because of such restrictions the mission definition is more specific and it is expected that this will facilitate more rapid system response to changes in launch date and/or landing site. With the exception of the second item on Viewgraph 27, all others are confirmations of previous program positions. Injection on the second orbit is a recent decision. Pacific injection was briefly in this list, but as was mentioned earlier, the moon appears inhospitable in the northwest where sites would be necessary to support this.

To accomplish the first lunar mission there are certain system capabilities which seem particularly important at this point in time. Viewgraph 28 contains four such items all of which have no direct counterpart for earth orbital missions. All of these stem in some way from the dynamic nature of the lunar landing missions and the existence of discrete launch windows during which missions can be conducted. Specific program activities have been identified, which support the development of each of these capabilities.

No other opportunities for additional mission definition are known to be pending and the planned capability of the system appears adequate.

R. L. Wagner

201-RLW-rcs

Attached
Viewgraph 1 - 28

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(Continued on Next Page)

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OUTLINE

(NOV. 22, 1966)

I PATTERN OF APOLLO MISSION OPPORTUNITIES

II MISSION PREPARATIONS PRIOR TO INITIAL LAUNCH OPPORTUNITY

III APOLLO SYSTEMS CAPABILITY TO:

1. HOLD
2. RECYCLE
3. RESCHEDULE

IV SUMMARY

PLANNING OF THE FIRST LUNAR LANDING MISSION

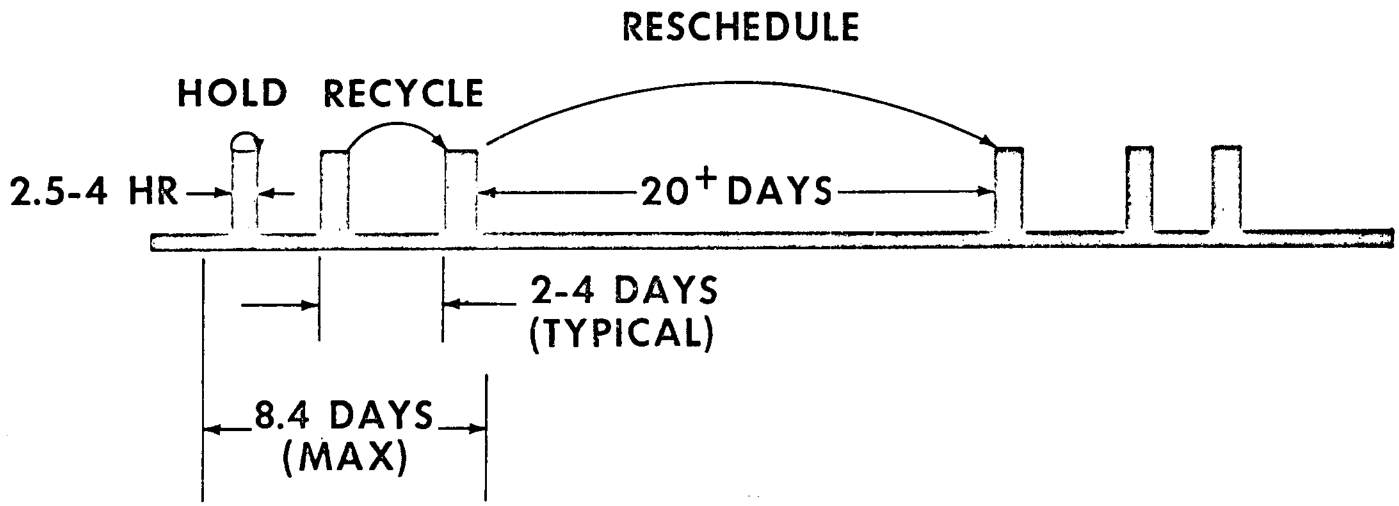
CONSTRAINTS:

- HARDWARE AVAILABILITY (SYSTEM READINESS)
- PERFORMANCE LIMITS (FUEL)
- LIGHTING AT LM LANDING
- SET OF CERTIFIED LUNAR LANDING SITES

PREFERENCES:

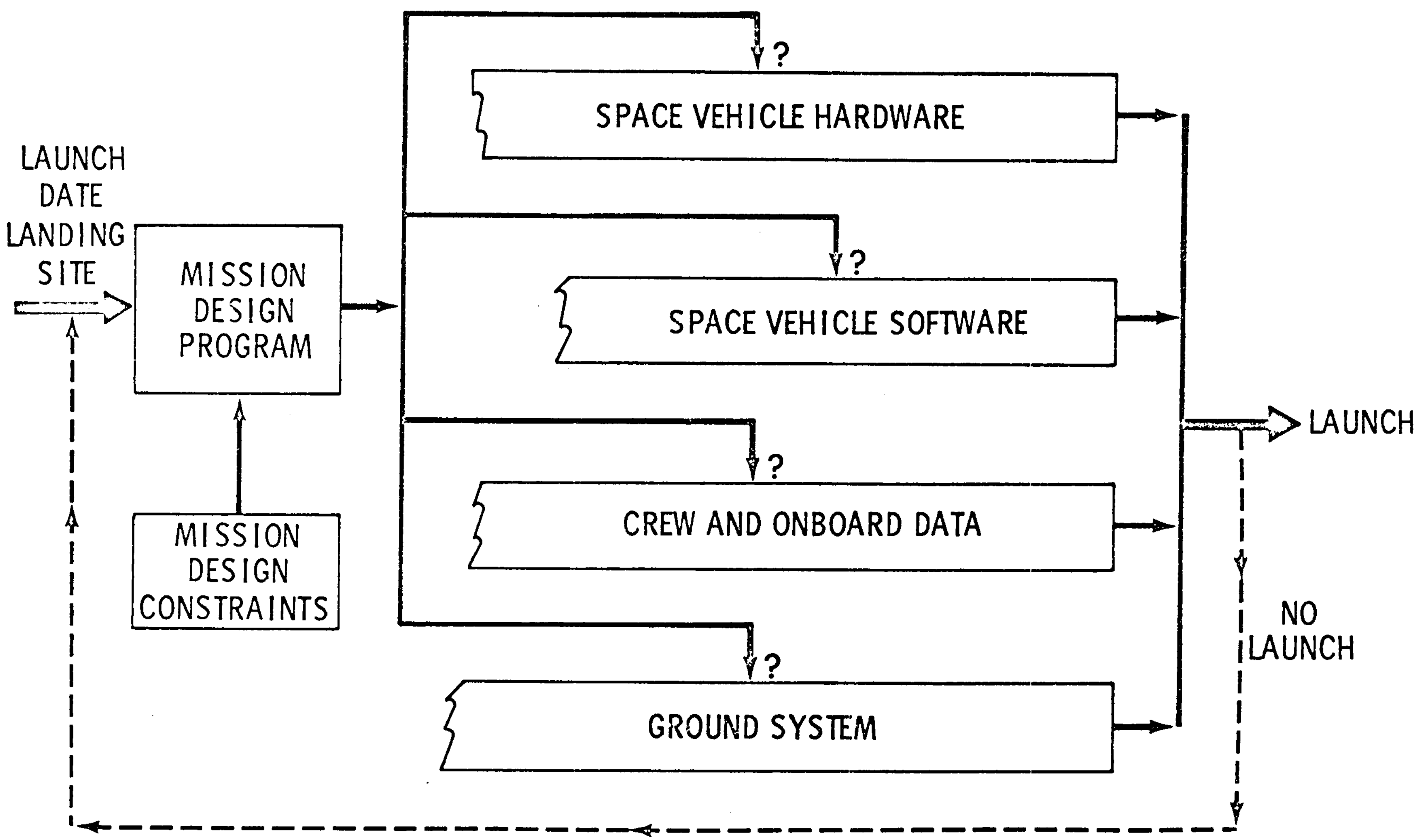
- FREQUENCY OF LAUNCH OPPORTUNITIES
- PERFORMANCE MARGINS
- LIGHTING AT EARTH LAUNCH

LAUNCH OPPORTUNITIES



NASA-S-66-11140 NOV 18

LUNAR MISSION PREPARATION PROCESS



- WHAT ARE THE MAJOR STEPS IN THE PROCESS?
- AT WHAT POINT IN EACH PROCESS IS MISSION DATA REQUIRED?
- HOW FAST CAN THE PROCESS BE REPEATED?

NASA-S-66-11148 NOV 18

SUMMARY OF SYSTEM REQUIREMENTS AND CAPABILITIES

	NEED MISSION DATA		HOLD	RECYCLE	RESCHEDULE
	TYPICAL	ACTUAL			
SPACE VEHICLE HARDWARE	T-2 1/2 MOS	T-1 MO	NO PROBLEM	44 HOUR RECYCLE UNCERTAIN	SC WILL NOT BE READY FOR THIRD MONTHLY WINDOW
SPACE VEHICLE SOFTWARE	T-5 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM
CREW AND ON BOARD DATA	T-5 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM
GROUND SYSTEMS	T-4 MOS	T-3 WKS	NO PROBLEM	NO PROBLEM	NO PROBLEM

PROGRAM REQUIREMENTS FOR THE FIRST LUNAR LANDING MISSION

- PLAN FOR LAUNCH OPPORTUNITIES ON THREE DAYS PER MONTH
- PLAN FOR MINIMUM OF 44 HOURS BETWEEN LAUNCH OPPORTUNITIES
- PLAN FOR PACIFIC INJECTIONS
- PLAN FOR TWO MONTH LEAD TIME FOR LAUNCH DATE AND LUNAR LANDING SITE IDENTIFICATION

OUTLINE
(JANUARY 24, 1967)

I. INTRODUCTION

II. MISSION DEFINITION AND PREPARATION

III. HARDWARE RECYCLE AND RESCHEDULE

IV. SUMMARY

NASA-S-67-103

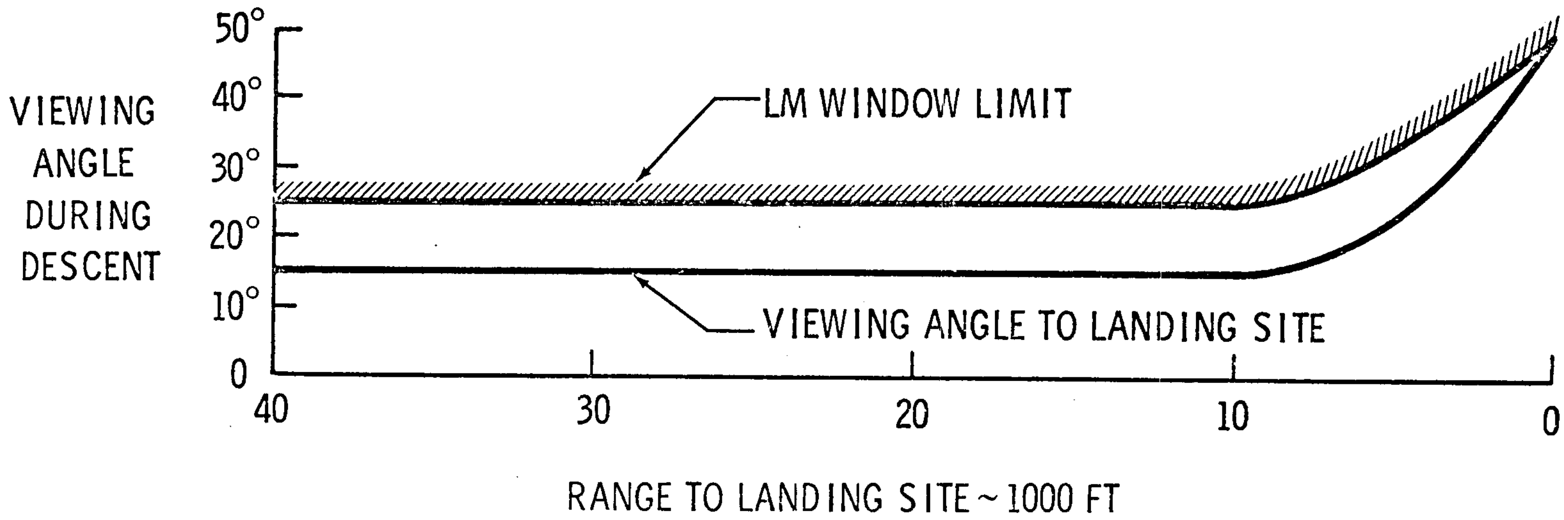
MISSION DEFINITION AND PREPARATION

- LIGHTING CONSTRAINTS AT LM LANDING
- DURATION OF THE EARTH LAUNCH WINDOW
- SELECTION OF THE EARTH ORBIT FOR TLI
- ONBOARD DATA PREPARATION
- STATUS OF THE TYPICAL MISSION DATA PACKAGE

NASA-S-67-405

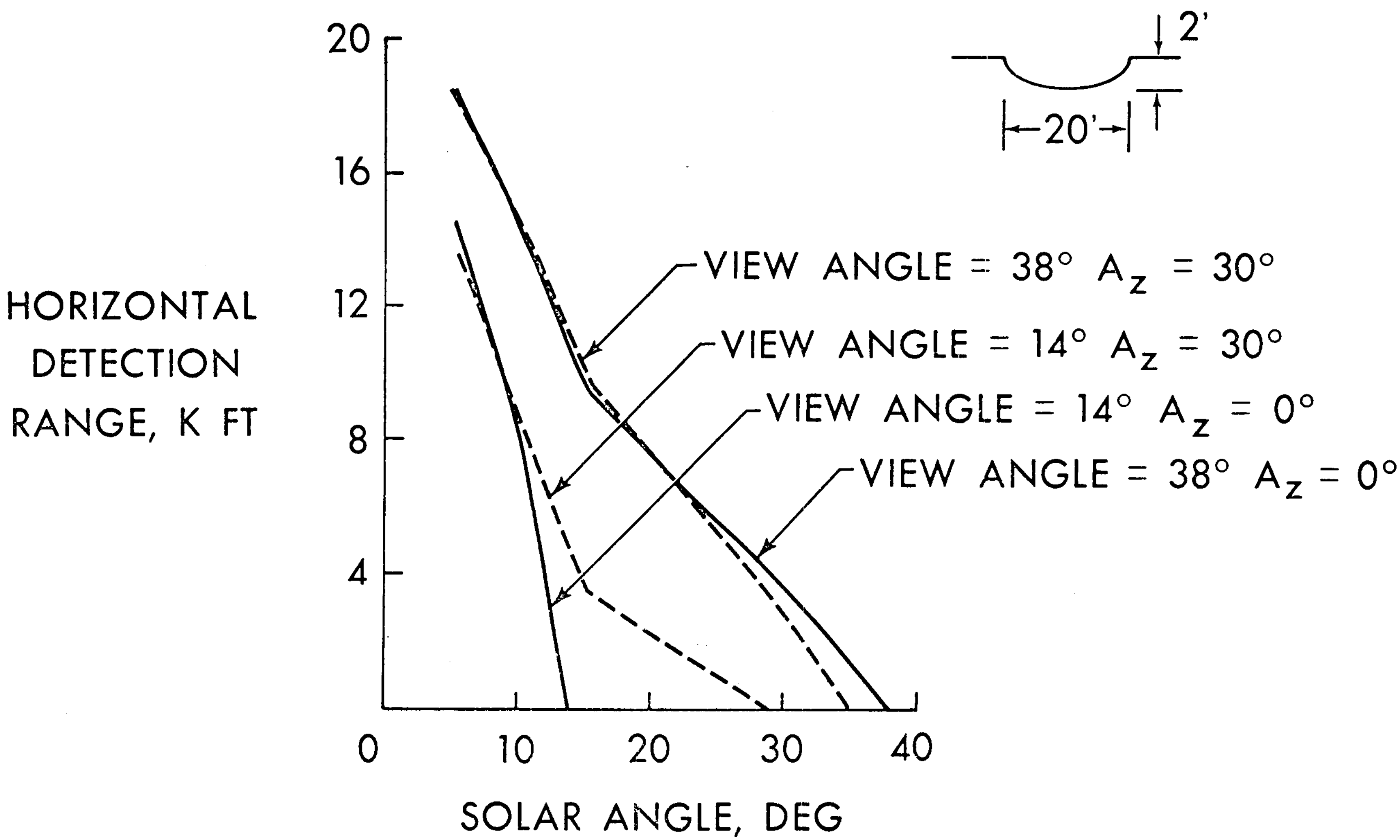
LIGHTING CONSTRAINTS AT LM LANDING

- MINIMUM SUN ELEVATION CRITERIA
  - MAXIMUM ALLOWABLE SURFACE SLOPE SHOULD BE ILLUMINATED → 7°
- MAXIMUM SUN ELEVATION CRITERIA
  - MOST CRATERS SHOULD CAST SHADOWS →22°
  - LIGHTING LIMIT SPREAD SHOULD BE AT LEAST 13° TO MAKE ALL SITES ACCESSABLE ONCE PER MONTH WITHOUT WAITING IN LUNAR ORBIT →20°
  - VIEWING ANGLE OF LANDING SITE SHOULD BE GREATER THAN SUN ELEVATION AT RANGE WHERE DETECTION AND RECOGNITION CAPABILITY ARE REQUIRED →15°



NASA-S-67-104

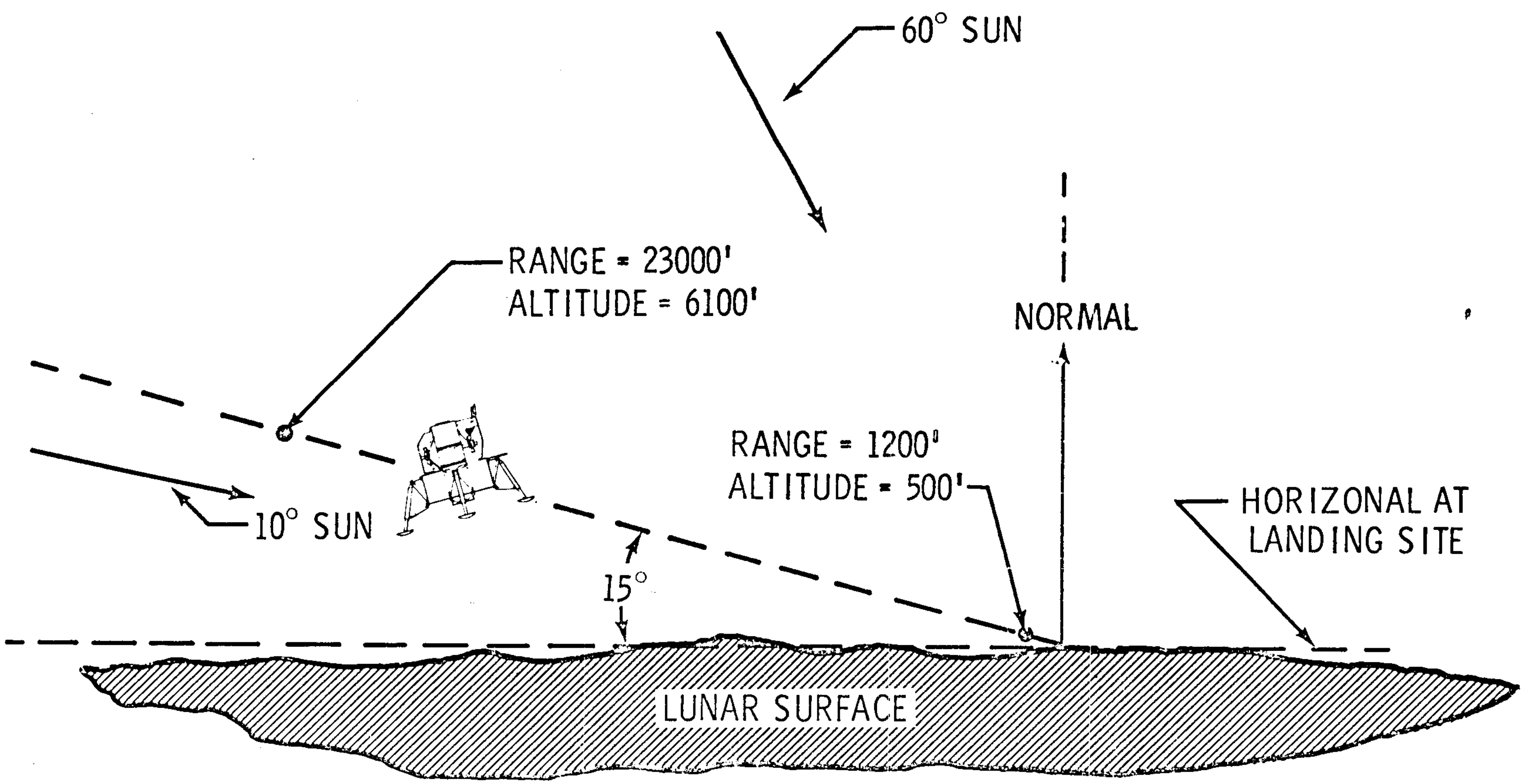
CRATER DETECTION RANGE



NASA-S-67-402

LIGHTING CONDITIONS SIMULATED BY FILM

FINAL APPROACH PHASE



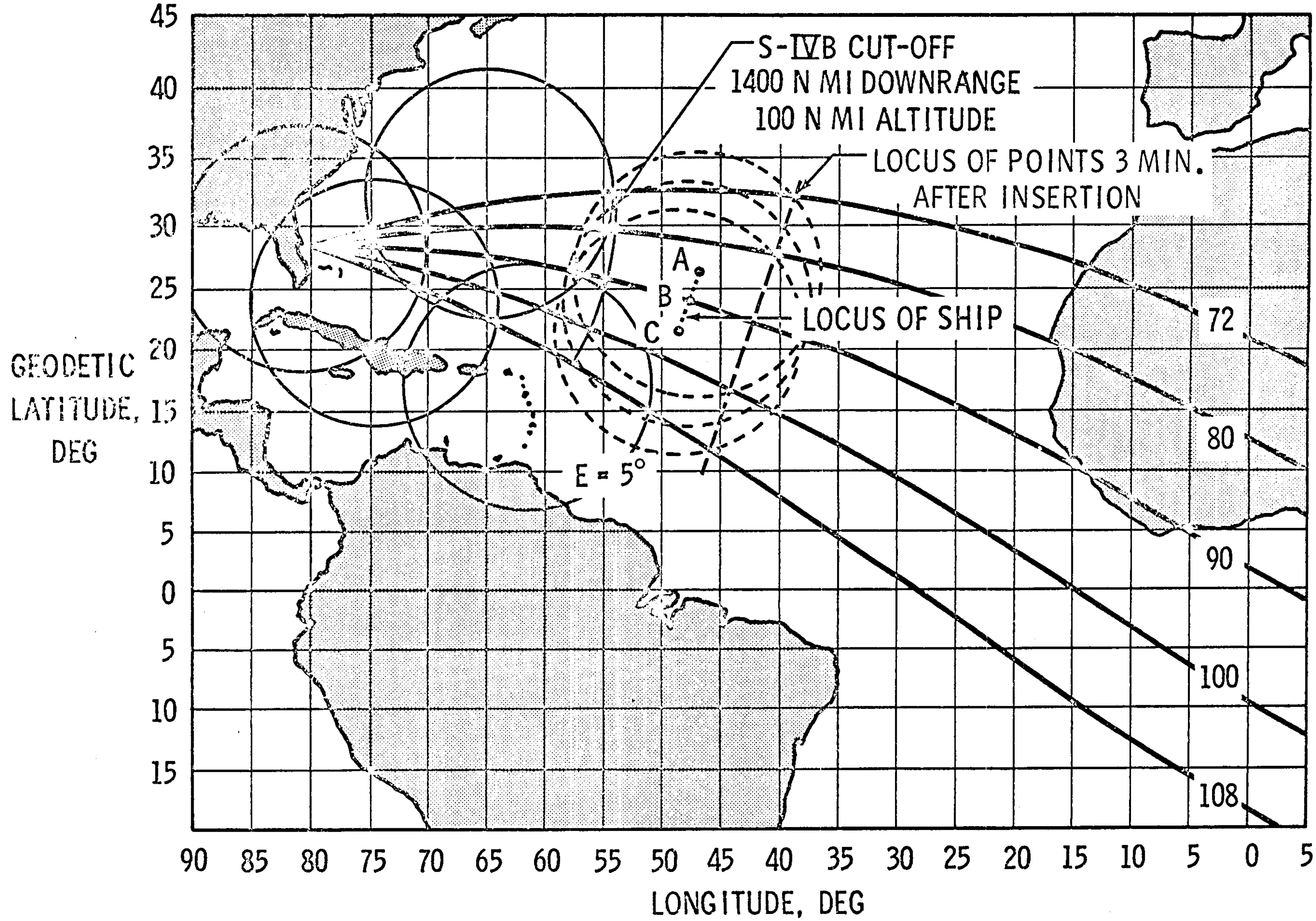
NASA-S-67-401

DURATION OF THE EARTH LAUNCH WINDOW

- RANGE SAFETY LIMITS
  - AVOID MORE DENSELY POPULATED LAND MASSES
- EARTH ORBIT INSERTION COVERAGE REQUIREMENTS
  - PROVIDE CONFIRMATION OF SAFE ORBIT
  - ASSIST IN ABORT TO ORBIT IF REQUIRED
- PAYLOAD PENALTY
  - PAYLOAD AT TLI DECREASE FOR LAUNCH AZIMUTHS OTHER THAN 90°

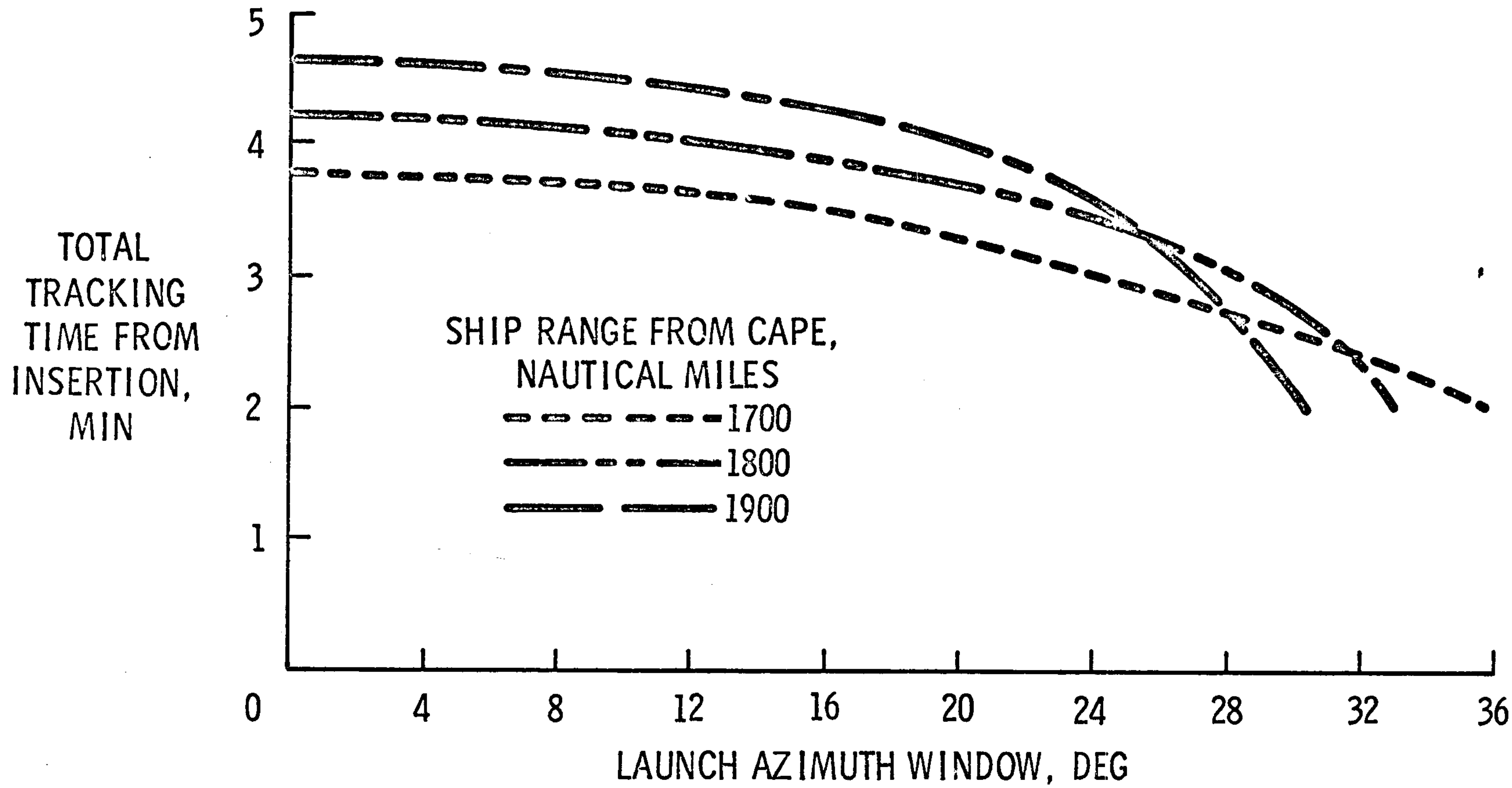
NASA-S-67-114

GROUND TRACKS FOR 72°-108° AZIMUTHS



NASA-S-67-116

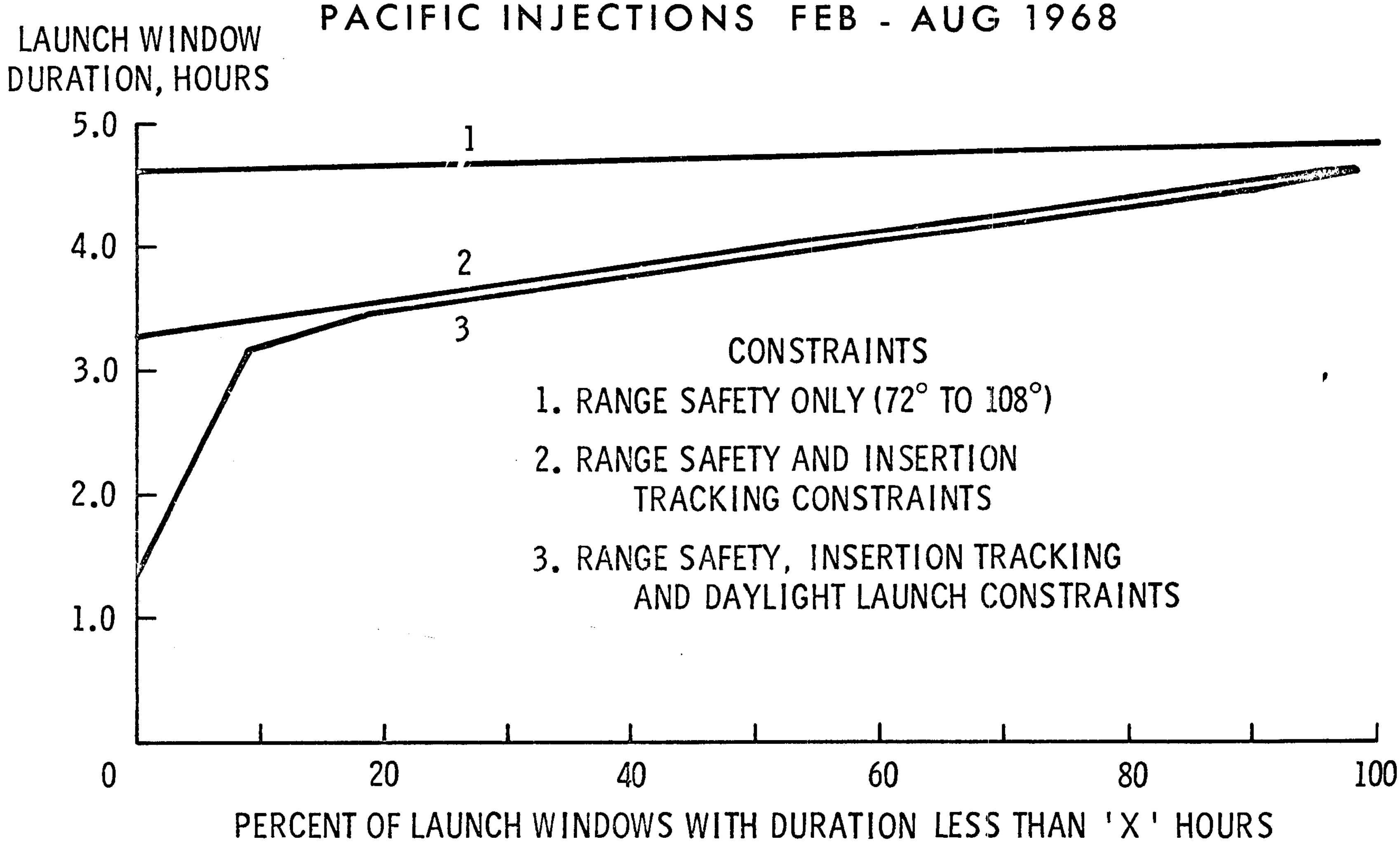
LAUNCH AZIMUTH WINDOWS DEFINED AS A FUNCTION OF TOTAL TRACKING TIME FOR VARIOUS SHIP POSITIONS



NASA-S-67-110

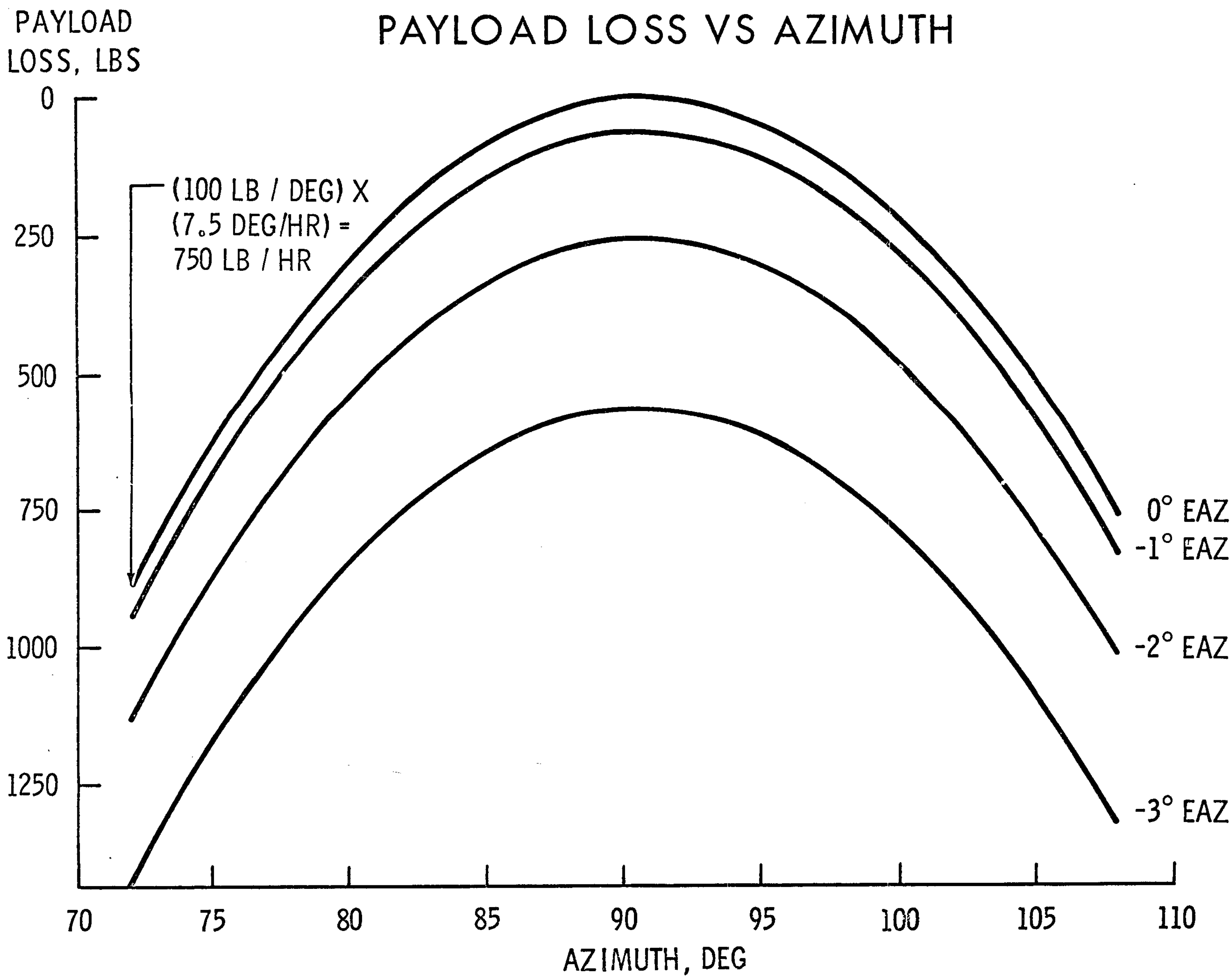
EFFECT OF CONSTRAINTS ON LAUNCH WINDOW DURATION

PACIFIC INJECTIONS FEB - AUG 1968



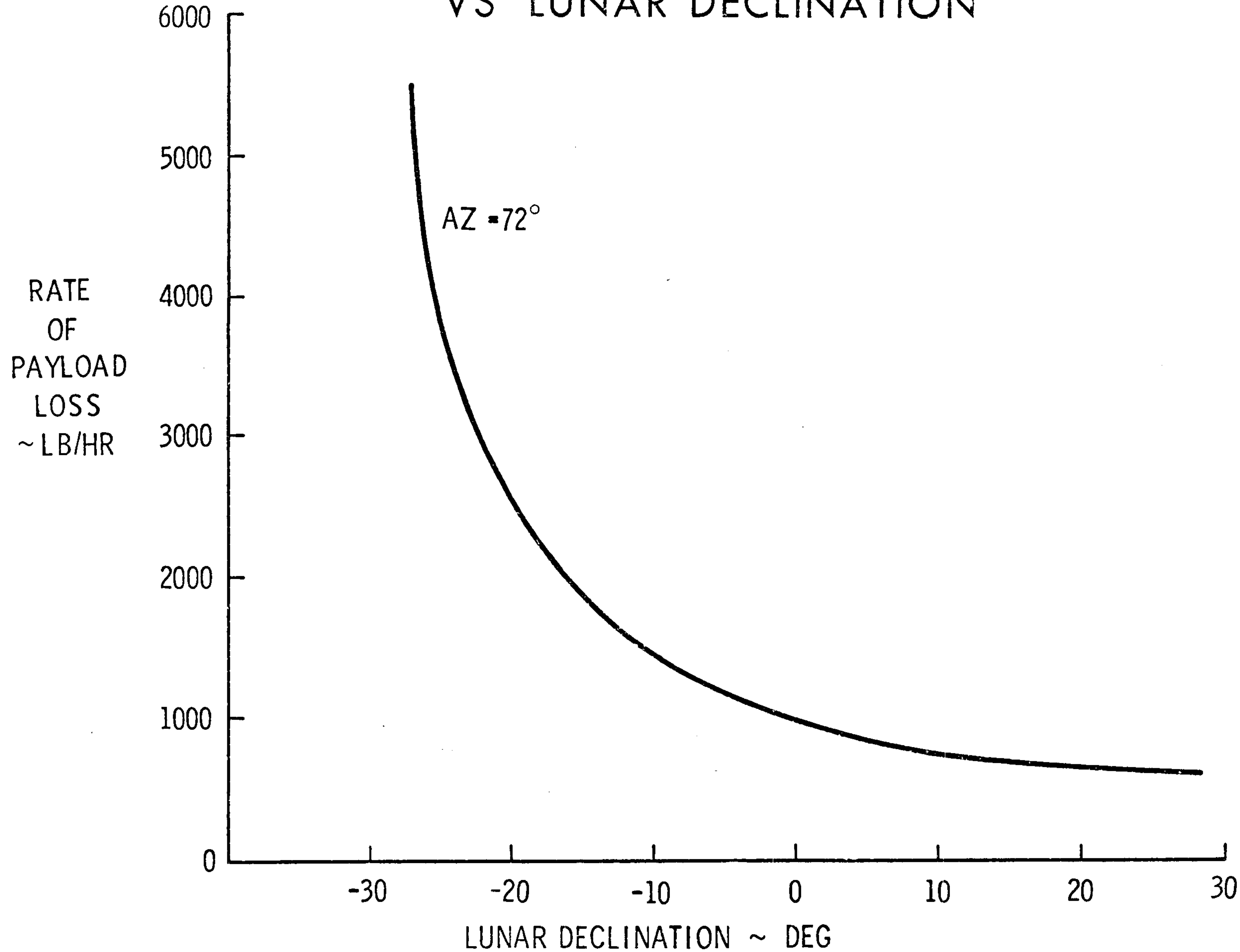
NASA-S-67-115

PAYLOAD LOSS VS AZIMUTH



NASA-S-67-403

PAYLOAD LOSS PER HOUR OF LAUNCH WINDOW INCREASE VS LUNAR DECLINATION



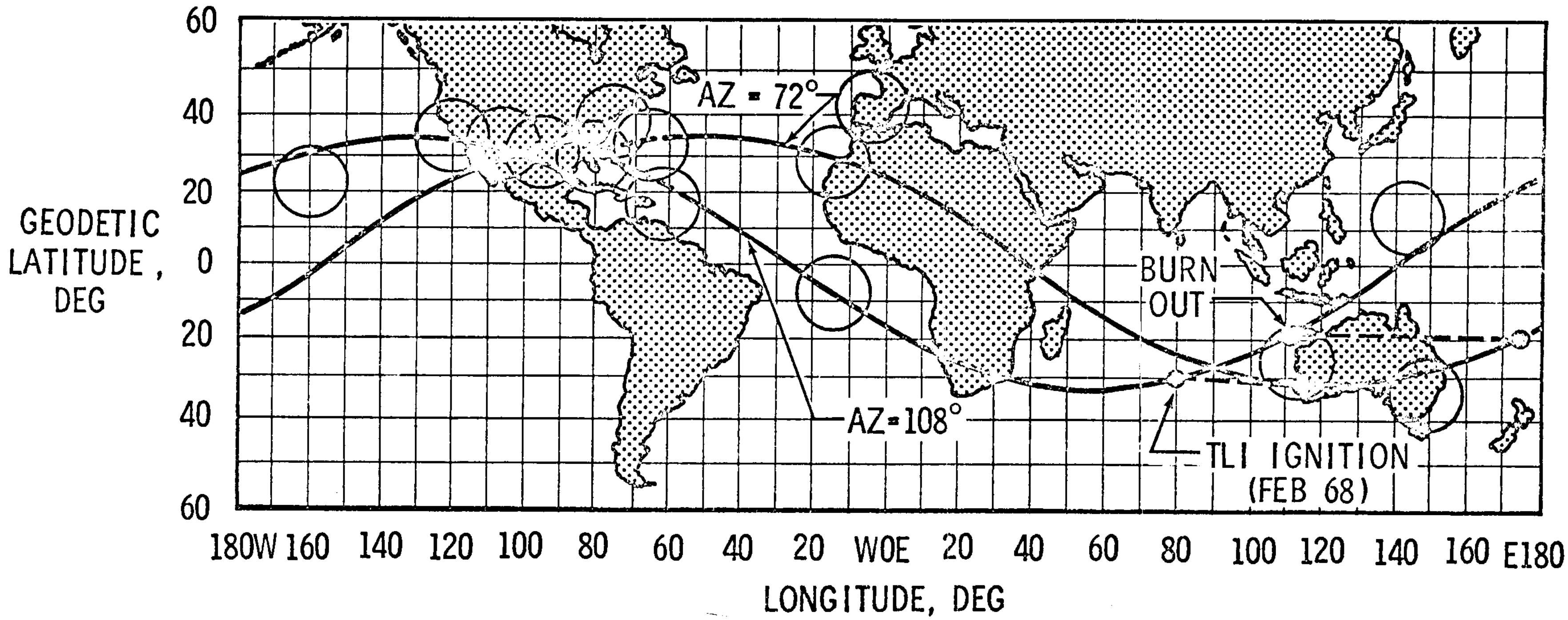
NASA-S-67-400

SELECTION OF EARTH ORBIT FOR TLI

- WHY SELECT NOW
  - ELIMINATE ANOTHER VARIABLE IN MISSION WITH ASSOSIATED STUDY EFFORT
  - ASSIST IN DEVELOPMENT OF EARTH ORBIT SC CHECKOUT PROCEDURES
- ALTERNATIVES
  - FIRST ORBIT PRIMARY, SECOND ORBIT BACKUP
  - SECOND ORBIT PRIMARY, THIRD ORBIT BACKUP
- ADVANTAGES OF FIRST ORBIT
  - MINIMIZE LIFETIME REQ'T OF S-IV B
  - REDUCES H_2 BOILOFF → 400 LB MORE PAYLOAD
- ADVANTAGES OF SECOND ORBIT
  - IMPROVE COVERAGE PRIOR TO TLI
  - PROVIDES CONTINGENCY TIME FOR SC OPERATIONS
  - MEETS 90 MINUTE COOL DOWN TIME ON J-2 ENGINE
- CONCLUSION
  - PLAN SECOND ORBIT PRIMARY FOR TLI

NASA-S-67-404

GROUND TRACK FOR FIRST ORBIT AT AZIMUTH OF 72° AND 108°



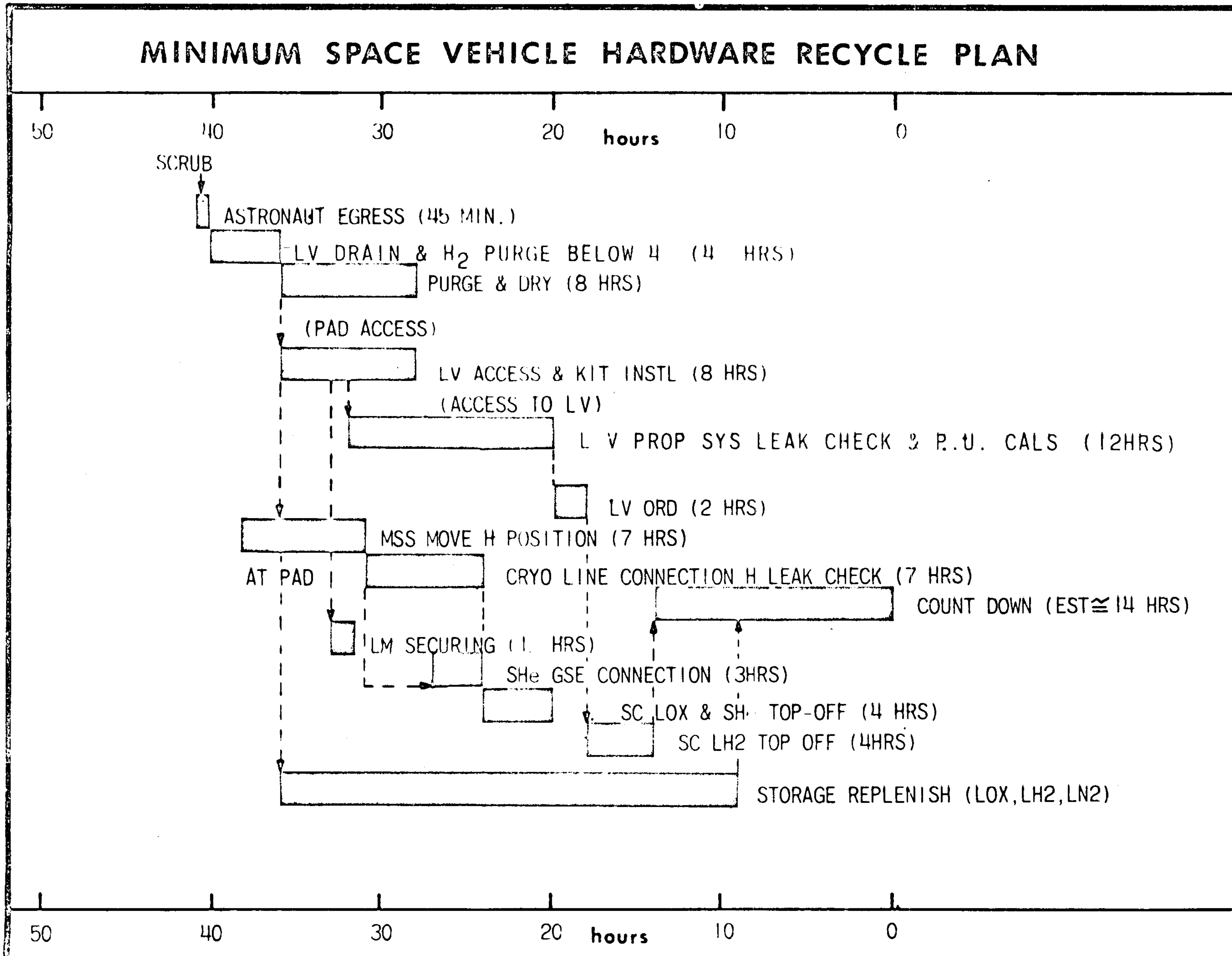
NASA-S-67-107

STATUS OF TYPICAL MISSION DATA PACKAGE

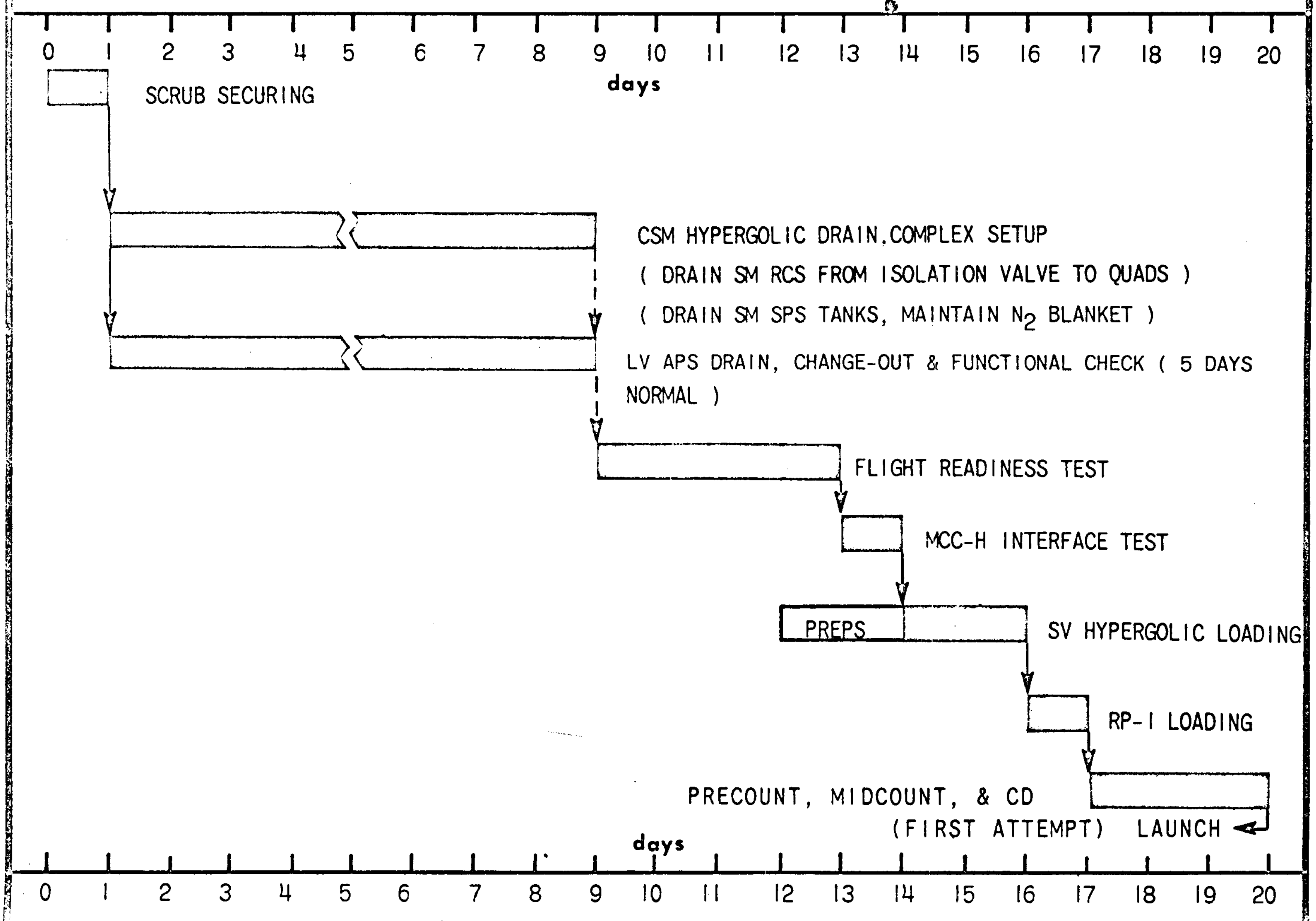
- USERS AND NEED DATES
  - SPACE VEHICLE HARDWARE: T- 2 1/2 MO.
  - SPACE VEHICLE SOFTWARE: T-5 MO.
  - CREW AND ONBOARD TRAINING: T-5 MO.
  - GROUND SYSTEMS: T-4 MO.
- PLAN
  - USE JOINT MSC / MSFC REFERENCE TRAJECTORY TO BE PUBLISHED JUNE, 1967
- CONTENT
  - DOCUMENT I - GENERAL EARTH PHASE SUMMARY DOCUMENT
  - DOCUMENT II - DETAILED DESCRIPTION OF THE FIRST MISSION IN THE MONTHLY LAUNCH WINDOW
  - DOCUMENT III - A SUMMARY DOCUMENT OF A SINGLE MISSION FOR THE FIRST INJECTION OPPORTUNITY OF EACH LAUNCH DAY IN THE MONTHLY WINDOW
  - DOCUMENT IV - A DOCUMENT SUMMARIZING THE VARIATION IN SIGNIFICANT TRAJECTORY PARAMETERS THROUGHOUT EACH DAILY LAUNCH WINDOW

HARDWARE
RECYCLE AND RESCHEDULE

- MINIMUM RECYCLE PLAN IN EVENT OF A SCRUB
- RESCHEDULE PLAN
    1. RETEST BETWEEN 1ST & 2ND LUNAR MONTHS
    2. THIRD MONTH CAPABILITY
- EXTENDED HOLD CAPABILITY


MINIMUM SPACE VEHICLE HARDWARE RECYCLE PLAN
50
40
30
20
hours
10
0
SCRUB
ASTRONAUT EGRESS (45 MIN.)
LV DRAIN & H_2 PURGE BELOW 4 (4 HRS)
PURGE & DRY (8 HRS)
(PAD ACCESS)
LV ACCESS & KIT INSTL (8 HRS)
(ACCESS TO LV)
L V PROP SYS LEAK CHECK & P.U. CALS (12HRS)
LV ORD (2 HRS)
MSS MOVE H POSITION (7 HRS)
AT PAD
CRYO LINE CONNECTION H LEAK CHECK (7 HRS)
COUNT DOWN (EST≅14 HRS)
LM SECURING (1 HRS)
SHe GSE CONNECTION (3HRS)
SC LOX & SH TOP-OFF (4 HRS)
SC LH2 TOP OFF (4HRS)
STORAGE REPLENISH (LOX,LH2,LN2)
50
40
30
20
hours
10
0

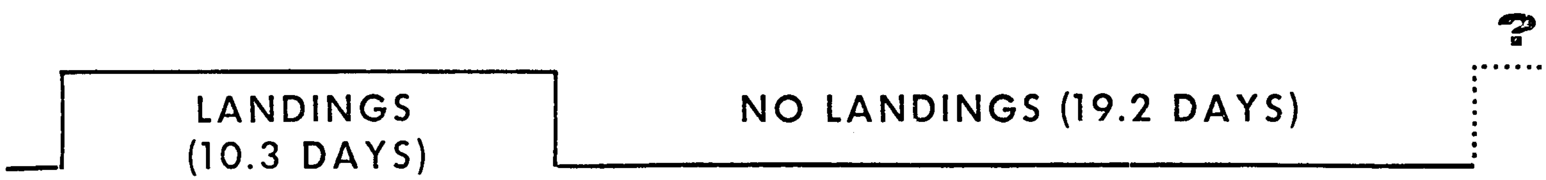
SPACE VEHICLE RESCHEDULE PLAN



LM LANDING OPPORTUNITIES

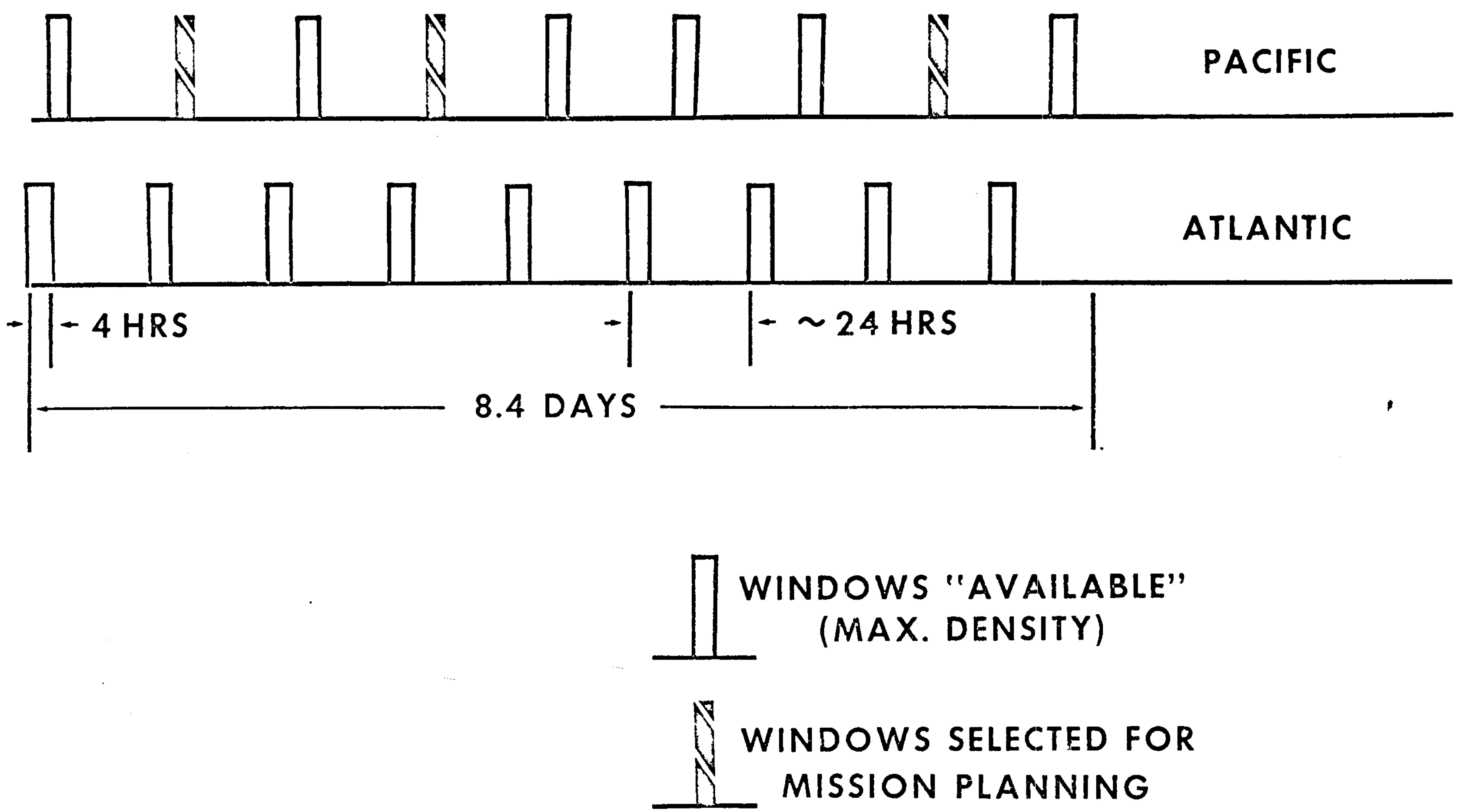
(SITE LONGITUDE BETWEEN + 45°)

13° RANGE OF ACCEPTABLE SUN ELEVATION ANGLES



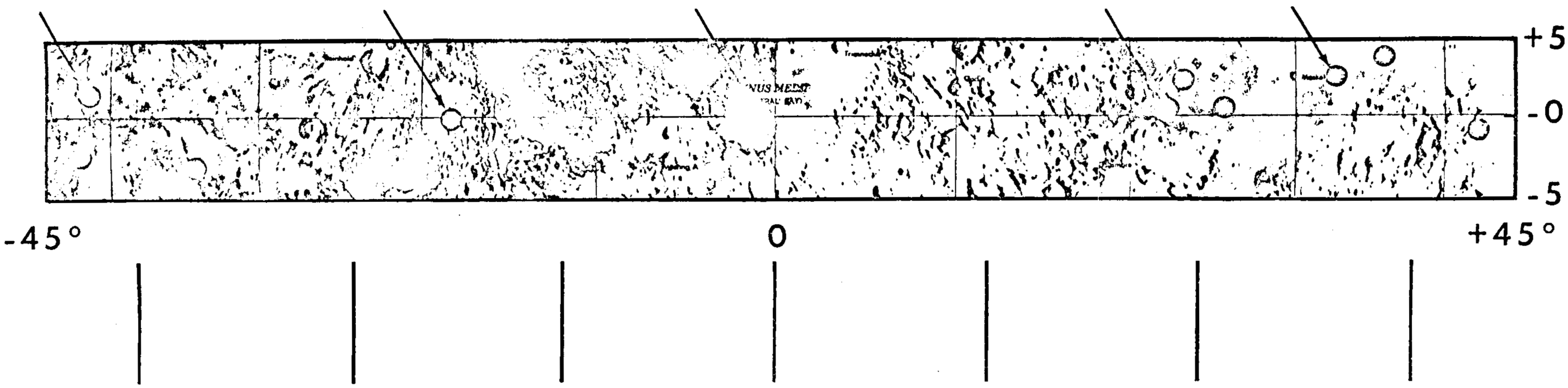
39° RANGE OF ACCEPTABLE SUN ELEVATION ANGLES

LAUNCH WINDOWS WITHIN ONE MONTHLY OPPORTUNITY



SOME OF THE MORE PROMISING AREAS FOR APOLLO SITES

(BASED ON LIMITED REDUCTION OF ORBITER DATA)



ONE DAY SPACINGS

SUMMARY OF RESTRICTIONS ON THE FAMILY OF MISSIONS FOR THE FIRST LUNAR LANDING

- FREE RETURN
- INJECTION ON THE SECOND EARTH ORBIT (PRIME)
- 7° TO 20° SUN ELEVATION AT LM LANDING
- MULTIPLE LUNAR LANDING SITES BETWEEN ±45° LONGITUDE

SUMMARY OF CRITICAL SYSTEM CAPABILITY FOR THE FIRST LANDING MISSION

- MOST PREPARATION TO BE DONE WITH TYPICAL MISSION DATA
- LUNAR LANDING SITE AND LAUNCH DATE DEFINED NO LATER THAN TWO MONTHS BEFORE LAUNCH
- A MAXIMUM OF THREE LAUNCH OPPORTUNITIES PER MONTH SPACED A MINIMUM OF 44 HOURS WITH LAUNCH WINDOWS UP TO 4 HOURS LONG
- TWO SUCCESSIVE MONTHS WITH THE SAME VEHICLE WITH SOME CHANCE OF A THIRD MONTH